Study to Determine the Biological Feasibility of a New Fish Tagging System

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A STUDY TO DETERMINE THE BIOLOGICAL FEASIBILITY OF A NEW FISH-TAGGING SYSTEM (1997 – 1998)

Annual Report

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EXECUTIVE SUMMARY

This report covers our work during 1997 and 1998 on a project to expand and improve technology for Passive-Integrated-Transponder tags (PIT tags) throughout the Columbia River Basin (CRB). The work was conducted in cooperation with the Bonneville Power Administration (BPA).

Timely and accurate information derived from PIT-tag technology is increasingly critical to resource stakeholders in assessing the effectiveness of efforts to enhance survival of juvenile and adult salmonids. Continued development of PIT-tag technology will enable researchers to address issues expressed in both the National Marine Fisheries Service (NMFS) biological opinion for operation of the Columbia River hydropower system and the proposed Snake River recovery plan. The work was divided into seven individual projects, which are covered separately in this report.

Transition to the 134.2-kHz ISO-Based PIT-Tag System

The present 400-kHz PIT-tag system in the CRB is scheduled to be replaced with a new 134.2-kHz system, based on documents published by the International Organization for Standardization (ISO), in time for the year 2000 smolt migration. To provide for a smooth transition and to ensure that CRB salmon research is not adversely affected, the entire system has to be thoroughly tested and evaluated prior to deployment of the new equipment.

To oversee the entire transition, BPA established the Transition Planning Team. To address individual system components, BPA established five additional technical teams: the activities accomplished by each team are itemized in this report. NMFS had representatives on all teams. The Transition Planning Team met on 9 September 1998 and reviewed progress to date on all components essential for meeting the proposed year 2000 time line. The team concurred that all components were or would be available in time to complete the changes required for the transition and recommended that the transition proceed as scheduled.

Development of a 134.2-kHz ISO-Based Flat-Plate System

NMFS and Patten Engineering, an outside contractor, have been working together to develop a 134.2-kHz ISO-based flat-plate system to replace the present 400-kHz flat-plate system at Bonneville Dam. Two prototype 134.2-kHz systems were developed and tested.

When the first prototype antenna system (it consisted of separate excitation and receive coils) was tested under field operating conditions at Bonneville Dam, it did not adequately read tags. The system was highly sensitive to noise caused by mechanical vibration and to other sources of electromagnetic interference. Two sources of the latter type of noise were identified. The prototype was then significantly modified (e.g., four smaller antennas replaced the single antenna) to reduce its sensitivity to noise. The redesigned antenna system was temporarily installed and evaluated at Bonneville Dam in November 1998. The redesigned antenna performed far better than the present 400-kHz system: it had a mean vertical read distance of 16.5 cm and tags could be read at angles greater than 45° (almost 90° in some locations on the antenna). In contrast, the 400-kHz system had a mean vertical read distance of 10 cm and could read tags only at orientations of up to 45°.

The 134.2-kHz ISO-based transceiver systems produced by three other manufacturers were also evaluated in November 1998. Tag-reading performances of these transceiver systems were equal to or less than that of the present 400-kHz system.

Measurements were made in February 1998 with the original prototype antenna system to determine whether it would meet Federal Communication Commission (FCC) requirements for electromagnetic field emission levels in low-power equipment. Results showed the larger antenna system would have passed FCC requirements. We expect that the smaller antennas will produce further reductions in electromagnetic field emissions; however, these tests have not yet been conducted.

Based on its superior performance over equipment produced by three other manufacturers, we recommend that the redesigned Patten Engineering system be used for the 134.2-kHz ISO-based flat-plate system at Bonneville Dam. Before installation at the dam, production electronics boards for various transceiver components must be fabricated, the components must be packaged, and diagnostic abilities must be added. These steps will be completed during 1999, and the flat-plate system will be installed in time for the year 2000 smolt migration.

PIT-Tag Detection of Adult Salmon at Dams

The ability to detect returning PIT-tagged adult salmon has long been a critical need for the fisheries community. The 400-kHz system can interrogate adult salmon transiting 31-cm pipes, but it is incapable of interrogating fish transiting orifices in fish ladders.

In 1998, we installed a 400-kHz PIT-tag interrogation system for adult salmon at the Bonneville Dam adult sampling and monitoring facility, where there were preexisting 31-cm flumes. The system, consisting of eight coils wrapped on two different 31-cm pipe sections, became functional on 23 April 1998. By the end of December 1998, it had detected 239 adult salmon.

The new adult interrogation system at Bonneville was also used for comparing performance between 400-kHz and 134.2-kHz ISO-based interrogation systems for adult salmon and for testing equipment changes proposed to allow the two systems to operate in close proximity. The 134.2-kHz ISO-based system cannot read tags if a 400-kHz field is present because a harmonic of the 400-kHz excitation signal causes excessive reading interference in the ISO-based system. It is critical to find a solution to this problem because both interrogation systems will need to be maintained simultaneously in the early 2000s, when adult fish tagged with both types of tags will be returning.

In late August, 1998 134.2-kHz ISO-based transceivers were installed at the site to make comparisons of tag-reading efficiencies (number of tags read in relation to the total number released) between the two interrogation systems. Tests using both adult fish and wooden sticks were conducted to determine reading efficiencies for both systems. Results from the stick tests showed that both systems had perfect reading efficiencies (i.e., 100%). Results from the fish tests showed that the 134.2-kHz ISO system consistently yielded 100% reading efficiencies, while the 400-kHz system read 4% to 12% lower, depending on which pipe was being evaluated.

To allow the 134.2-kHz ISO-based system to read tags when the 400-kHz system is operated in close proximity, we experimented with frequencies close to 400 kHz to find a frequency that could operate without causing interference to the 134.2-kHz ISO system. Our preliminary tests showed that changing the frequency of the 400-kHz system to 402.6 kHz would allow tags to be read by the 134.2-kHz system. This was confirmed by field tests at the Bonneville Dam adult sampling and monitoring facility, where both systems running simultaneously read 100% of the tags released. To implement the 402.6-kHz system, existing 400-kHz exciter crystals would need to be replaced with 402.6-kHz crystals. This is a straightforward and low-cost solution.

We also began a program to develop 134.2-kHz ISO-based systems for fish ladders because most dams in the CRB do not have facilities that include or can accommodate 31-cm pipes. During 1997 and 1998, this work consisted of forming a multi-agency oversight committee, evaluating the electronic limitations of the present ISO-based technology, and designing housings for antennas to be installed into orifices. Lead agencies for the Adult Salmon PIT-Tag Oversight Committee (ASPTOC) include BPA, the U.S. Army Corps of Engineers (COE), and NMFS. The purpose of this committee is to keep the entire fisheries community informed of progress, and at the same time to provide guidance to the development program.

Several approaches were employed to evaluate electronic limitations of the present ISO-based technology. By the summer of 1998, transceivers from three manufacturers were available for evaluation, and we analyzed and tested the circuitry of all three. In addition, knowledge regarding equipment limitations was gained by testing the transceivers with various antenna configurations.

We constructed a full-scale model of the reinforcement-bar layout for a weir to determine the effects of steel reinforcement bar on antenna electrical loading, tuning, and tag detection under several different antenna configurations. Preliminary results indicated that one manufacturer's transceiver performed better than the others under these "orifice-like" conditions. More importantly, however, results from electronic tests in general suggested that the 134.2-kHz ISO-based system installed into a 3,721-cm^2 square orifice (the most common size in CRB ladders) should be able to read tags successfully.

Based on results from these electronic tests, the ASPTOC approved a series of tests to be conducted in 1999-2000 at Bonneville Dam. For these evaluations, NMFS designed three styles of PIT-tag antenna housings for orifices that are described in detail in this report. It is important to note that none of the three antenna housing designs will compromise the structural integrity of the weirs or significantly alter existing orifice hydraulic conditions. The electronic tests during 1998 were significant in determining how the antennas were wrapped inside these different housings. Prototypes of the three housing designs will be installed in the Cascades Island Fish Ladder at Bonneville Dam during 1999. Different transceiver systems will be attached to these antennas and tested. Housing design recommendations and recommendations on the transceiver systems most appropriate for orifice passage should be possible following these evaluations.

Continued Operation of 400-kHz Pass-By (Flat-Plate) and Pass-Through PIT-Tag Interrogation Systems at Bonneville Dam

In 1996, NMFS installed a prototype 400-kHz pass-by (flat-plate) PIT-tag interrogation system in the downstream migrant (DSM) channel of Bonneville Dam First Powerhouse. In 1997, we installed a pass-through PIT-tag interrogation system and two-way side-to-side fish diversion gate in the DSM channel of Bonneville Dam Second Powerhouse. To ensure reliable operation of these systems, NMFS conducted maintenance evaluations on both systems prior to and during the 1998 field season. In addition, fish tests were conducted to directly determine tag reading efficiencies of both systems. For the pass-through system, the overall reading efficiency of the four coils combined was 98.2%. For the pass-by (flat-plate) system, the overall reading efficiencies for the two coils combined were 86% and 100% for the tests conducted in March and April, respectively. Details of these tests are presented in this report.

The pass-through system was removed at the end of the 1998 field season in preparation for the new collection and interrogation facility for juvenile salmon that is being constructed by the COE. Because this system provides data considered critical by fishery researchers and managers throughout the CRB, a temporary pass-through PIT-tag interrogation system will be installed for the 1999 field season.

Three-Way Side-to-Side Fish Diversion Gate

In 1997, NMFS constructed a prototype three-way side-to-side fish diversion gate. The general operating principle for side-to-side diversion gates is that fish pass through a flexible hose section connected to a track; the hose is moved sideways along the track to the different diversion pathways. However, the longer side-to-side travel distance of the three-way diversion gate (compared to a two-way gate) causes hose fatigue, and two material formulations for hoses tested in 1997 failed long before completing the objective of 80,000 cycles. In 1998, a material formulation was found that produced a hose that passed the 80,000 cycle test.

Results from the 1997 evaluation using fish were inconclusive as to whether the three-way diversion gate caused any new scale loss or other injuries to test fish, and after some precautionary modifications, further tests were conducted in 1998. Results showed that even when the discharge nozzle of the hose was centered on a pathway divider, no subsequent abrasion marks were observed in fish. Thus, the three-way side-to-side diversion gate has passed all preliminary mechanical and biological tests, and we recommend the gate be evaluated at a dam as the final step in its development.

Separation-by-Code System: Computer Program (MULTIMON)

During 1992-1994 at the NMFS Manchester Research Station, we developed and evaluated a separation-by-code system, which consists primarily of a computer program and fish diversion gates. The computer program controls the separation of targeted PIT-tagged fish from untargeted tagged and untagged fish based on their individual tag codes. Since 1996, this computer program has been called MULTIMON. The development of MULTIMON is a joint project with the U.S. Department of Energy Pacific Northwest National Laboratory (PNNL), whose personnel write the computer code.

Since it was introduced at the dams in 1995, each year has seen new features added to MULTIMON to assist researchers in completing their studies. Before the 1998 migration season, the largest set of changes made was to adapt MULTIMON so it could run in a DOS window within the multi-tasking Windows 95 platform. The multi-tasking environment allowed closed data files to be automatically e-mailed by a second program, MAILER, to the Pacific States Marine Fisheries Commission (PSMFC) server at Gladstone, Oregon while MULTIMON continued to operate.

Other features added in 1998 included new separation and subsampling abilities, improved counting efficiency, and improved data-transfer capability. These changes were needed because the program has reached a stage where NMFS and PSMFC agree that after the conclusion of the 1999 field season, the primary responsibility of maintaining MULTIMON will be transferred to PSMFC. These changes will facilitate the transition through improved versatility, flexibility, speed, and ease of use. Details of these improvements and others are presented in this report.

Information Transfer, Technical Reviews, and Technical Support

As in previous years, NMFS actively advised other agencies on PIT-tag related matters, such as facility designs to accommodate PIT-tag systems, PIT-tag system maintenance, assistance in using prototype equipment and the MULTIMON computer program, and information transfer. Because NMFS personnel designed or co-developed many of the present PIT-tag systems and their components, and because they provide technical support and training to ensure the reliable operation of these systems, these personnel are an important resource for users of PIT-tag technology throughout the CRB. Specific technology transfer activities of NMFS personnel during the 1997-1998 reporting period are itemized in this report.

CONTENTS

EXECUTIVE SUMMARY i

INTRODUCTION 1

DEVELOPMENT AND EVALUATION OF PIT-TAG TECHNOLOGY 2

Transition to the 134.2-kHz ISO-Based PIT-Tag System for Juvenile Pacific Salmon 2

Introduction 2

Transition Planning Team 3

Transceiver Technical Evaluation Team 3

Portable Transceiver Evaluation Team 7

Tag Development Team 7

Infrastructure Team 8

Development of a 134.2-kHz ISO-Based Flat-Plate System 9

Introduction 9

Testing 9

Conclusions and Recommendations 11

PIT-Tag Detection of Adult Salmon at Dams 12

Introduction 12

Installation of a 400-kHz Adult Interrogation System 12

Comparison between 400-kHz and 134.2-kHz ISO-Based Systems 13

Simultaneous Operation of 400-kHz and 134.2-kHz PIT-Tag Interrogation Systems 15

Development of 134.2-kHz ISO-Based Systems for Fish Ladders 16

Continued Operation of the 400-kHz Pass-By (Flat-Plate) and Pass-Through PIT-Tag Interrogation Systems at Bonneville Dam 22

Introduction 22

Maintenance 22

Fish Tests for the Pass-By (Flat-plate) Interrogation System 23

Fish Test for the Pass-Through Interrogation System 24

Conclusions and Recommendations 24

Three-Way Side-to-Side Fish Diversion Gate 25
Introduction 25
Mechanical Evaluation 25
Biological Evaluation 27
Conclusions and Recommendations 28
Separation-by-Code System: Computer Program (MULTIMON) 29
Introduction 29
1998 Computer Program Modifications 30
Problems in 1998 34
Conclusions and Recommendations 35
Information Transfer, Technical Reviews, and Technical Support 36

ACKNOWLEDGMENTS 37

REFERENCES 38

APPENDIX A: FISH TESTS PERFORMED AT JOHN DAY AND McNARY DAMS 39

INTRODUCTION

The National Marine Fisheries Service (NMFS) in cooperation with the Bonneville Power Administration (BPA) conducted research and development work to expand and improve technology for Passive-Integrated-Transponder tags (PIT tags) throughout the Columbia River Basin (CRB). The work conducted during 1997-1998 was divided into seven individual projects, which are covered separately in this report.

The efforts by personnel associated with this project have produced and will continue to produce products that aid resource stakeholders in assessing the effectiveness of actions taken to enhance the survival of juvenile and adult salmonids. These products and their uses include

- Survival and migration timing information on stocks to evaluate water management strategies and fish passage/collection facilities.
- Data needed for the management and restoration of salmonids and other fish stocks.
- Information required for the management of multiple species in a variety of habitats.
- Tools that will enable fisheries researchers and managers to address previously unanswerable questions.

These products are also used in genetic, physiology, behavior, and captive broodstock research on endangered species. The continued development of PIT-tag technology will enable researchers to address issues expressed in both the NMFS 1995 biological opinion for operation of the federal Columbia River hydropower system and the proposed Snake River recovery plan (Tasks 2.1D, 2.3.b.4, 2.4.a, 2.6.c.2, and 2.9.d).

DEVELOPMENT AND EVALUATION OF PIT-TAG TECHNOLOGY

Transition to the 134.2-kHz ISO-Based PIT-Tag System for Juvenile Pacific Salmon

Introduction

The present 400-kHz PIT-tag system in the CRB is scheduled to be replaced with a new 134.2-kHz system based on documents of the International Organization for Standardization (ISO) in time for the year 2000 smolt migration. To provide for a smooth transfer and to ensure that CRB salmon research is not adversely affected during the transition, the entire system has to be thoroughly tested and evaluated prior to the deployment of the new equipment. All essential components must be available in time to complete the changes required for the transition. These components include portable and stationary transceivers, tags, infrastructure assessments, installation schedules, and systems management tools.

The BPA has established a Transition Planning Team to oversee the entire transition and the following multi-agency technical teams to address individual system components:

Team	Area of Oversight
Transceiver Technical Evaluation Team	Development of stationary transceivers
Portable Transceiver Evaluation Team	Development of portable readers
Tag Development Team	Development of suitable PIT tags
Infrastructure Team	Plan and oversee construction necessary at the dams for the transition, installation of stationary transceivers, and necessary changes to tagging software and PTAGIS database for implementing the 134.2-kHz ISO-based system.

Activities completed by NMFS representatives on each of these teams during 1997 and 1998 are itemized below, along with the conclusions and recommendations formed by each team.

Transition Planning Team

Activities

Participated in meetings and conference calls with the multiple agency team to discuss the progress of the various technical teams and to make decisions on schedules.

Conclusions and recommendations

The Transition Planning Team met on 9 September 1998 and reviewed progress to date on all components (stationary and portable transceivers, tags, infrastructure needs, installation schedules, and systems management tools) essential for meeting the proposed year 2000 time line. The team concurred that all of the components were or would be available in time to complete the changes required for the transition. Therefore, they recommended that the transition proceed and the new system be on-line for the year 2000 smolt migration.

Transceiver Technical Evaluation Team

Activities

- Met with Destron-Fearing (manufacturer of PIT-tag equipment and tags) to agree on the modifications necessary to improve the prototype stationary 134.2-kHz ISO-based transceivers (i.e., the 1997 models installed at McNary Dam) so that they would meet CRB requirements.

- Collaborated with Destron-Fearing and their subcontractor to make firmware changes required to meet the diagnostic needs of the fisheries community. Tested the firmware changes for performance and consistency.

- Visited Destron-Fearing's factory to review the quality assurance process and the manufacturing of the 134.2-kHz ISO-based stationary transceivers. These processes include a number of tests and inspections during the assembly of each unit to evaluate the functionality and performance of each transceiver.

- Headed the team that used PIT-tagged fish to evaluate the stationary 134.2-kHz ISO-based transceivers at McNary and John Day Dams.

- Prepared reports summarizing the fish tests conducted at McNary and John Day Dams (see Appendix A for a summary of these tests).

- Analyzed the results of weekly stick tests performed during the fall of 1998 at McNary Dam. These tests consist of four different tag types being inserted into sticks at various angles and passed through the detector antennas to determine the performance of the transceivers.

- Analyzed the results of monthly electronic tests performed by Pacific States Marine Fisheries Commission (PSMFC) during 1998.

- Participated in meetings and conference calls to accomplish the above tasks.

Conclusions and recommendations

The 1998 134.2-kHz ISO-based stationary transceivers performed as well as or better than the 400-kHz system in all of the fish tests at McNary and John Day Dams (see Appendix A). Only one component in one transceiver failed during the season compared to multiple failures in the prototype transceivers installed during 1997. The manufacturing acceptance tests seem sufficient to ensure that high-quality transceivers will be produced. The manufactured units are scheduled to be delivered during the summer of 1999.

The stationary 134.2-kHz ISO-based transceiver system is quite different from the present 400-kHz system (Figs. 1-2). Improvements in electronic technology have reduced the size of components such that in the new system, one package holds the power supply, electronics to create the excitation signal, and electronics to decode the return tag-code signal. Since this system employs point-to-point communication, there is also one stationary ISO-based transceiver for each coil instead of the dual-coil arrangement in the present 400-kHz system.

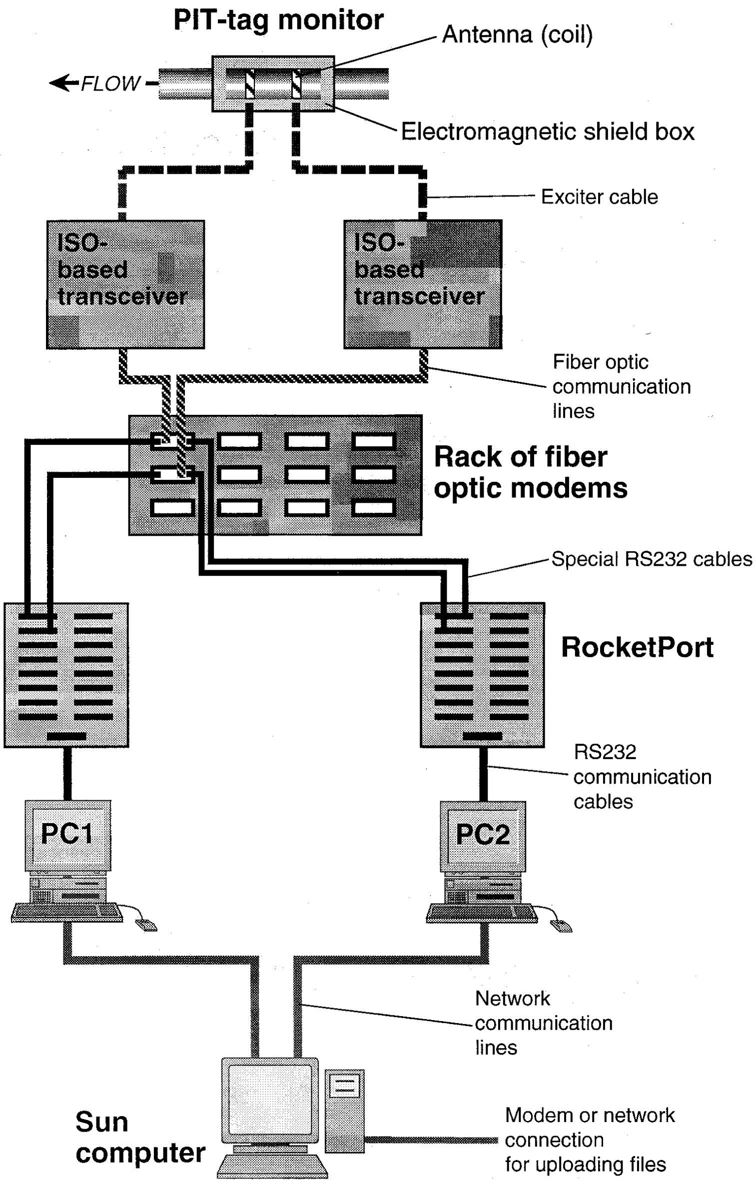

Figure 1. General schematic of a stationary 134.2-kHz ISO-based transceiver system that will be used at all Columbia River Basin dams starting in 2000.

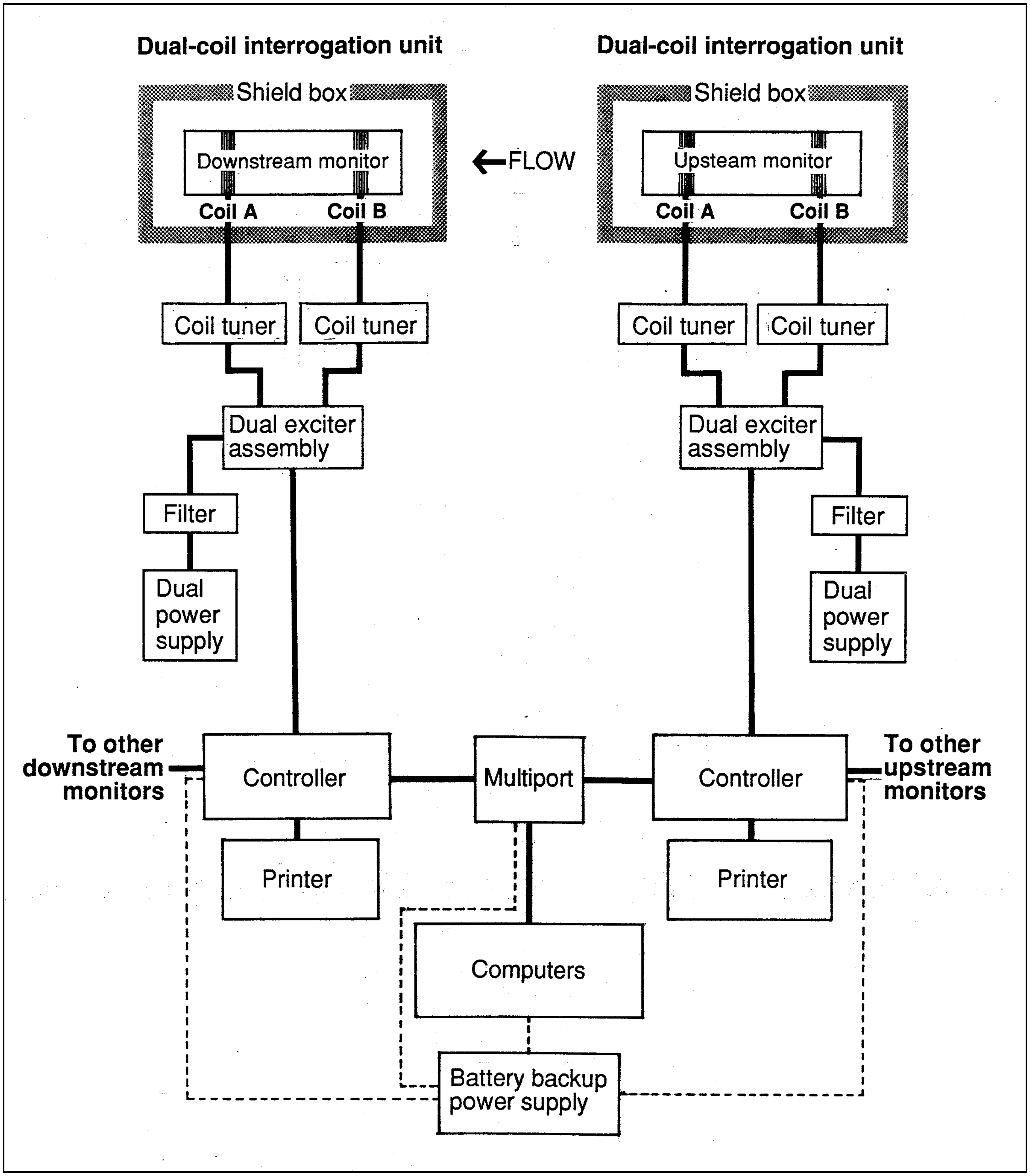

Figure 2. General schematic of a 400-kHz PIT-tag interrogation system. Notice the dual-coil dependency in the design.

Portable Transceiver Evaluation Team

Activities

- Assisted in the two evaluations of the ISO-based portable PIT-tag transceivers.
- Assisted in writing the test results on the portable reader evaluation.
- Participated in meetings and conference calls associated with the above tasks.

Conclusions and recommendations

The portable transceivers passed the second round of evaluations. Two hundred portable transceivers are scheduled for delivery to BPA in early 1999.

Tag Development Team

Activities

- Evaluated new 12-mm tags produced by Destron-Fearing (December 1997) and Datamars (November 1997) with the belt system at the NMFS Manchester (Washington) Research Station.
- Helped develop tests for evaluating tags to determine whether they meet CRB requirements.
- Worked on the development of non-fish tests that will provide results that correlate with reading efficiency results found in the fish tests.
- Participated in conference calls and meetings associated with the above tasks.

Conclusions and recommendations

The 12-mm tags produced by Datamars and Destron-Fearing after December 1997 should satisfy CRB requirements. BPA has a contract with Destron-Fearing to buy their 12-mm tags exclusively through 2001.

Infrastructure Team

Activities

- Helped identify locations for the installation of ISO-based transceivers, electrical junction boxes, and fiber-optic patch-panels at juvenile collection facilities in the CRB.

- Helped develop acceptance tests for approving the installed transceivers.

- Participated in meetings associated with the above tasks.

Conclusions and Recommendations

In order to ensure that electrical and communication line installations are completed in time to meet the year 2000 transition deadline, it will be necessary to turn off the 400-kHz PIT-tag systems at Lower Granite, Little Goose, and Lower Monumental Dams on 1 September 1999. At McNary Dam, the 400-kHz system will be turned off on 1 October 1999. Installation of all necessary equipment is scheduled for completion by mid-March of 2000. Acceptance testing will conclude by mid-April.

Development of a 134.2-kHz ISO-Based Flat-Plate System

Introduction

In anticipation of replacing the existing 400-kHz flat-plate PIT-tag interrogation system at Bonneville Dam in 2000, NMFS began development work in 1997 on a 134.2-kHz ISO-based flat-plate system. NMFS and Patten Engineering, an outside contractor, have jointly worked on the 134.2-kHz flat-plate antenna and receiver design and electronics fabrication. Patten Engineering is the contractor that successfully designed the 400-kHz flat-plate system presently deployed at Bonneville Dam. In late 1997, the contractor evaluated several antenna designs in his shop and selected one for further development. The antenna selected had the same overall dimensions (213-cm long by 43-cm wide) as the present 400-kHz system, yet provided a tag-read distance greater than the present system under optimal conditions.

Testing

Laboratory tests were conducted using the belt system at the NMFS Manchester Research Station in January 1998. Tag-read distance and speed were found to be sufficient to meet interrogation needs at Bonneville Dam. However, it was found that this antenna (it consisted of separate excitation and receive coils) was highly sensitive to noise caused by mechanical vibration and to other sources of electromagnetic interference. The 400-kHz system uses a different signaling scheme and thus is not susceptible to these vibration noises. To determine how seriously this noise sensitivity would affect performance under actual operating conditions, the prototype system was temporarily installed and evaluated at Bonneville Dam in February 1998.

When tested under actual operating conditions at Bonneville Dam, the prototype system did not adequately read tags. Two sources of vibration at this site appeared to contribute to electrical noise levels that prevented PIT tags from being read. The first source was the relative movement between the excitation and receive antenna pair within their housing. The second source was the vibration of metallic structures (primarily the fish sampling box) surrounding the antenna, which created electromagnetic field disruption noises.

Field disruption noises result from the excitation current in the 134.2-kHz antenna generating a magnetic field, which extends several meters out from the antenna assembly, that induces currents in all surrounding metal parts. If these metal parts have poor or intermittent conducting joints, the induced magnetic field passing through the material is disrupted, and this interruption causes modulation of field intensity. These modulations are similar to modulations of the field caused by a PIT tag, and therefore interfere with tag detection. Because the magnetic field is proportional to antenna size, this problem increases as antenna size increases.

During the summer and fall of 1998, the prototype antenna was modified in four ways to reduce noise sensitivity. First, since field disruption noises increase as antenna size increases, an array of multiple smaller antennas was designed to replace the one large antenna; second, these antennas were designed with a single winding rather than one for excitation and another for receiving; third, measures were taken to reduce vibration in the fish sampling box by installing nonmetallic wheels; and fourth, the transceiver circuitry design was improved to better filter out extraneous noise.

To test this redesigned Patten Engineering system, two antenna arrays were fabricated that consisted of four antennas each; in this arrangement, each antenna independently excited the tags and received their tag-code signals. The antennas were also potted to reduce internal vibration.

The redesigned Patten Engineering system was temporarily installed and evaluated at Bonneville Dam in early November 1998 using velocities normal for this facility. It performed far better than the present 400-kHz system: mean vertical read distance was 16.5 cm and tags could be read at angles greater than 45° (almost 90° in some locations on the antenna) compared to a read distance of 10 cm and the ability to effectively read tags at angles up to 45° for the present 400-kHz system. The major disadvantage of the redesigned system was that it would require eight transceivers for the two antenna arrays instead of the single transceiver used by the present 400-kHz system; however, the system could be deployed using the existing cable guide system and equipment racks. Transceiver systems produced by three other manufacturers were also evaluated in November 1998. Tag-reading performances of these transceiver systems were equal to or less than the 400-kHz system.

Measurements were made in February 1998 with the original Patten Engineering prototype antenna system to determine whether it could meet Federal Communication Commission (FCC) electromagnetic field emission levels for low power equipment. Measurements taken both at NMFS Manchester Research Station and at Bonneville Dam showed that the 134.2-kHz system had lower emissions than the 400-kHz system. Therefore, the large antenna should pass FCC requirements for low-power devices: active antennas would be safe for humans located a distance of 1 m or more away.

Conclusions and Recommendations

Based on its superior performance over equipment produced by three other manufacturers, NMFS is recommending that the redesigned Patten Engineering antenna system be used for the 134.2-kHz ISO-based flat-plate system at Bonneville Dam. Even though the large antenna system tested for satisfying FCC requirements will not be used because of its poor performance, emission findings from these tests were important in indicating that the general design approach of the Patten Engineering system was satisfactory and did not need to be modified. It is expected that using smaller antennas will further reduce electromagnetic field emissions. However, these tests have not yet been conducted.

A number of steps still need to be completed before the redesigned Patten Engineering antenna system is ready for installation at Bonneville Dam. These steps include fabricating production electronic boards for various transceiver components, packaging the components, and adding diagnostic abilities. In addition, another antenna design will be evaluated in the laboratory in an attempt to decrease the number of transceivers required for this application. Then the final product will be re-tested at Bonneville Dam. These steps will be completed in time for the system to be installed for the year 2000 smolt migration.

PIT-Tag Detection of Adult Salmon at Dams

Introduction

The detection of returning PIT-tagged adult salmon has long been a critical need for the fisheries community. The 400-kHz system can interrogate adult salmon transiting 31-cm pipes, but it is incapable of interrogating fish transiting orifices in fish ladders. In 1998, NMFS installed a 400-kHz PIT-tag interrogation system for adult salmon at Bonneville Dam where there were preexisting 31-cm round-bottomed flumes in the adult sampling and monitoring facility.

The new Bonneville site was also used for comparing performance between the 400-kHz and 134.2-kHz ISO-based interrogation systems for adult salmon and for testing equipment changes proposed for allowing the two systems to operate within close proximity. The present ISO-based system is incapable of reading tags near a 400-kHz field. It is critical to find a solution to this problem because both interrogation systems will need to be maintained at monitoring facilities for adult salmon in the early 2000s when fish tagged with both types of tags return simultaneously.

Unfortunately, most of the dams in the CRB do not have facilities that include or can accommodate 31-cm pipes. Therefore, NMFS started a program to develop 134.2-kHz ISO-based systems for fish ladders. This work consisted of forming a multiple agency oversight committee, evaluating the electronic limitations of the present ISO-based technology, and designing housings for antennas to be installed into orifices. These activities are described below.

Installation of a 400-kHz Adult Interrogation System

Discussion

On 23 April 1998, a 400-kHz PIT-tag interrogation system became functional at the Bonneville Dam adult sampling and monitoring facility. Two preexisting 31-cm round-bottomed flume sections were replaced with two 31-cm pipes, designated pipes A and B. Four coils were then wrapped around each pipe section. These pipes were connected to the established flume arrangement that ends in the fish sampling area. The coils are only active during periods when the facility is used by investigators (i.e., about 40 hours per week). The site is designated B2A in the PTAGIS database managed by PSMFC. From its installation in April through December 1998, the system detected 239 adult salmon.

Conclusions and Recommendations

Installation of a 400-kHz PIT-tag interrogation system for adult salmon at the Bonneville Dam test site has given the fisheries community considerably more information on returning salmon than was previously available. Before this installation, the only information on adult returns was from the adult detectors at Lower Granite Dam (the uppermost dam on the lower Snake River, seven dams upstream from Bonneville Dam). In addition, the adult interrogation system at Bonneville provided an essential location for evaluations of other critical components in PIT-tag technology, described in the following two sections.

Comparison between 400-kHz and 134.2-kHz ISO-Based Systems

Background

In late August 1998, 134.2-kHz ISO-based transceivers were temporarily installed at the Bonneville Dam adult interrogation site. The purpose of these installations was to make comparisons of tag-reading efficiency (number of tags read in relation to the total number released) between the two interrogation systems while they operated under the same conditions.

Testing

On one pipe, the two-coils for the 134.2-kHz ISO-based system were installed upstream from the four 400-kHz coils. On the other pipe, the two coils were installed downstream from the 400-kHz coils. All six coils on each pipe were contained within a single shield box.

Both fish and stick tests were conducted to determine reading efficiencies for the two interrogation systems. Fish tests used surplus adult chinook salmon (*Oncorhynchus tshawytscha*) from Bonneville Dam Hatchery. The fish had fork lengths that ranged from 640 to 920 mm. Wooden test sticks were 35-cm long and had either two 134.2-kHz ISO-based tags inserted into the ends, with one in optimal reading orientation (0°) and the other at 45° orientation, or a single 400-kHz tag inserted into one end in optimal orientation (0°). We assumed that tag orientation was close to optimal for adult salmon transiting these small pipes.

During these tests, only one interrogation system was active at a time because the 134.2-kHz ISO-based system cannot read tags when a 400-kHz system is operating in close proximity. Sticks and fish were introduced at the top of the two pipes (A and B) leading to PIT-tag interrogation coils. The sticks and fish were then collected from the fish sampling area and reintroduced until a minimum of 20 fish or sticks of one tag type (134.2 kHz or 400 kHz) had passed through each set of coils. Reading efficiencies were calculated for the whole pipe; thus, they combined data from two coils for the 134.2-kHz ISO-based system and from four coils for the 400-kHz system.

Results from the stick tests showed that both interrogation systems had perfect reading efficiencies (i.e., 100%) with tags inserted in optimal orientation, and the 134.2-kHz system also had 100% reading efficiencies for tags inserted at 45° (Table 1). Results from fish tests showed that the 134.2-kHz system had a higher reading efficiency than the 400-kHz system. The 134.2-kHz system consistently yielded 100% reading efficiencies, while the 400-kHz system read 88% in pipe A and 96% in pipe B.

Table 1. Reading efficiencies (REs) for the different stick and fish tests conducted at the adult sampling and monitoring facility at Bonneville Dam to compare the performances of the 134.2-kHz ISO-based and 400-kHz interrogation systems. Only one system was active at a time.

	Test description		0° tags		45° tags	
Stick/Fish	Frequency (kHz)	Pipe	No. tags	RE(%)	No. tags	RE(%)
Stick	134.2	A	78	100	78	100
Stick	134.2	B	65	100	65	100
Stick	400	A	90	100	--	---
Stick	400	B	80	100	--	---
Fish	134.2	A	20	100	--	---
Fish	134.2	B	24	100	--	---
Fish	400	A	25	88	--	---
Fish	400	B	25	96	--	---

Conclusions and Recommendations

Comparisons of reading efficiency between the 400-kHz and 134.2-kHz ISO-based systems indicated that the ISO-based system performed as well as or better than the 400-kHz system.

Simultaneous Operation of 400-kHz and 134.2-kHz PIT-Tag Interrogation Systems

Background

The 134.2-kHz ISO-based system is now incapable of reading tags if a 400-kHz field is present. It is critical to find a solution to this problem because both interrogation systems will need to be maintained at monitoring facilities for adult salmon in the early 2000s, when fish tagged with both types of tags return simultaneously. The ISO-based system cannot read tags when a 400-kHz system is operated in close proximity because a harmonic of the 400-kHz excitation signal causes excessive tag reading interference in the 134.2-kHz ISO-based system. However, since the 400-kHz tags are not tuned, it is possible to excite them using frequencies other than 400-kHz.

Testing

In the NMFS Sand Point Electronics Shop, we tested frequencies close to 400-kHz to determine whether any of them produced harmonics that could be filtered out by the ISO-based system. These tests determined that an excitation frequency of 402.6-kHz appeared to work. Belt tests (tests using a motor-driven belt apparatus) at Manchester confirmed that the reading efficiencies of the ISO-based system were identical with and without the 402.6-kHz signal present.

The final test was to confirm these results at a dam site and to determine whether the 400-kHz system read as well when it was excited by a 402.6-kHz field. This was done in a series of tests performed at the Bonneville Dam adult interrogation site in September 1998. Only stick tests were conducted because fish were unavailable. Because of a lack of equipment, only one pipe was analyzed at a time, but all six coils were active simultaneously during each test. The two coils for the 134.2-kHz ISO-based system were connected to separate transceivers, and the four coils for the 402.6-kHz system were connected to standard 400-kHz transceivers operated at 402.6 kHz; a signal generator was used to produce the 402.6-kHz signal source.

Results were positive as both systems read 100% of the tags, indicating that the 402.6-kHz system did not interfere with the ISO-based system during this test (Table 2).

Table 2. Reading efficiencies (RE) for the stick tests conducted at the adult sampling and monitoring facility at Bonneville Dam to determine if operating at 402.6-kHz eliminated interference on the 134.2-kHz transceivers. Both systems were active during these tests.

Test description		0° tags		45° tags	
Frequency (kHz)	Pipe	No. tags	RE (%)	No. tags	RE (%)
134.2	A	40	100	40	100
402.6		40	100	--	--
134.2	B	50	100	50	100
402.6		40	100	--	--

Conclusions and Recommendations

Reading efficiency tests confirmed that changing the excitation signal from 400 to 402.6 kHz would enable both interrogation systems to read tags simultaneously. To implement the 402.6-kHz system, existing 400-kHz exciter crystals would need to be replaced with 402.6-kHz crystals. This is a straightforward and low-cost solution.

Development of 134.2-kHz ISO-Based Systems for Fish Ladders

Background

The 400-kHz system can interrogate adult salmon transiting 31-cm pipes, but it is incapable of interrogating fish transiting orifices in fish ladders. Unfortunately, most dams in the CRB do not have facilities that include or can accommodate 31-cm pipes. Therefore NMFS started a program to develop 134.2-kHz ISO-based systems for fish ladders. During 1997 and 1998, this work consisted of forming a multi-agency oversight committee, evaluating the electronic limitations of the present ISO-based technology, and designing housings for antennas to be installed into orifices.

Oversight Committee

In order to keep all resource stakeholders informed on development of an interrogation system for adult salmon, and at the same time provide guidance to the development program, an Adult Salmon PIT-tag Oversight Committee (ASPTOC) was formed in May 1998. Lead agencies include BPA, the U.S. Army Corps of Engineers (COE), and NMFS. Committee members agreed that NMFS should initially concentrate its development efforts on interrogating adult salmon in the orifices of fish ladders.

Electronic Testing

Several approaches were employed to evaluate the electronic limitations of the present 134.2-kHz ISO-based technology. By the summer of 1998, transceivers from three manufacturers (Destron-Fearing, Patten Engineering, and Datamars) were available for evaluation. In order to become familiar with the equipment, it was necessary to analyze and test the circuitry of the different transceivers. In addition, knowledge regarding equipment limitations was gained by testing the transceivers with various antenna configurations.

In addition to evaluating commercially available transceivers, NMFS has been working on improvements to the limited functionality of the digital portion of these transceivers. The inability to match digital circuitry with different analogous detection circuits has been a weak link in designing PIT-tag systems for several applications, such as adult, flat-plate, and towed-array detectors. To avoid this problem in the future, NMFS has been designing digital transceiver circuitry and looking for a commercially available single-board computer with enough flexibility to interface with almost any analog circuit from any manufacturer. The key to this versatility is to structure the firmware so that functions can be easily added or modified, and to incorporate enough functionality on the digital board to handle all control and communications requirements. NMFS is working with the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) on writing the firmware. Bench testing of the first "bread board" system was found to be satisfactory. Development of the firmware will continue.

To learn more about how the different transceivers might work in an orifice, a full-scale model was constructed of the reinforcement-bar layout based on the blueprints for a weir in the Cascades Island Fish Ladder. This model was used to determine the effect of steel reinforcement bar on antenna electrical loading, tuning, and tag detection using several different antenna configurations. Preliminary results indicated that one manufacturer’s transceiver did better under these “orifice-like” conditions. These tests were also instrumental in determining how the antennas in the different housings should be wrapped for the initial evaluations at Bonneville Dam (see below).

Antenna Housings

For evaluations at Bonneville Dam, NMFS designed three styles of PIT-tag antenna housings (Figs. 3-5) for orifices. The first design was an extension-only housing that would attach to the upstream face of the orifice, where it would extend approximately 12 cm. This design would require minimum concrete cutting (the reinforcement bar in the weir wall needs to be cut to reduce the electrical loading on the antenna, but the wall is left intact). The second design (insert only) is inserted into the orifice opening and is the same thickness as the weir wall. The concrete weir wall and floor would need to be cut to maintain the existing orifice dimensions after the insert is installed. The third design (insert with extension) combines the other two: the antenna housing was designed to be inserted into the orifice opening and extend upstream 12 cm. This design would permit a wider coil, or possibly two coils, to be installed in the same housing. None of the antenna housing designs would compromise the structural integrity of the weirs or significantly alter existing orifice hydraulic conditions.

Conclusions and Recommendations

Electronic evaluations of the present 134.2-kHz ISO-based technology indicated that there are transceiver systems available that should be sufficient for interrogating fish swimming through 3,721-cm^2 square orifices (the size of most orifices in the CRB). However, until additional tests are conducted in the field under actual working conditions, it is not possible to recommend which transceiver system will be best for an orifice application. Therefore, we recommend that the proposed tests for Bonneville Dam approved by the ASPTOC be conducted.

In order to evaluate the three orifice antenna configurations in the proposed tests for Bonneville Dam, we recommend that all three designs be installed in the Cascades Island Fish Ladder, and at least two of the designs should be installed this year in the exit ladder of the adult sampling and monitoring facility. Several transceiver systems should be tested with each antenna design. Tag-reading efficiency, fish response to the antenna housings, and overall electronic performance of the various systems needs to be evaluated.

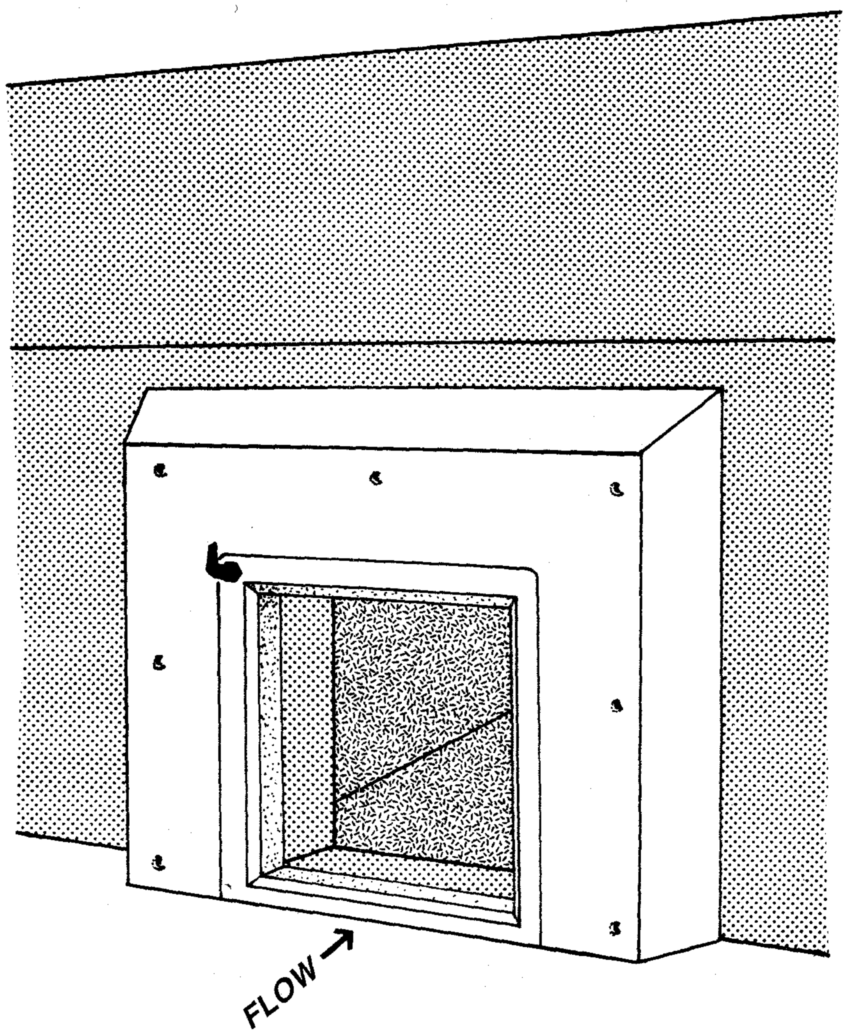

Figure 3. Diagram showing an extension-only housing that attaches to the upstream face of an orifice.

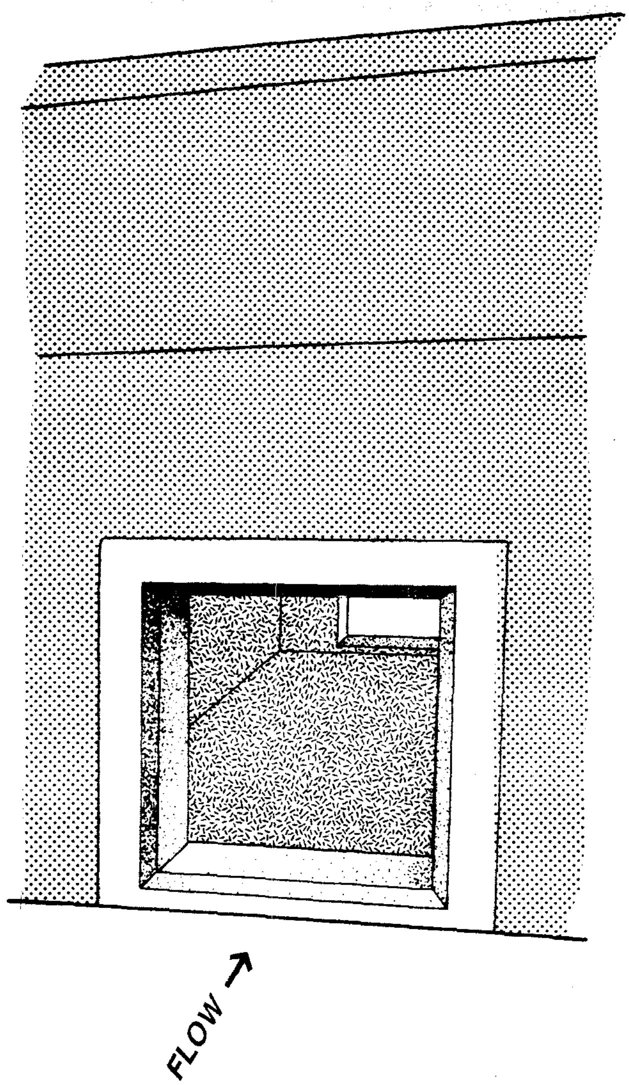

Figure 4. Diagram showing an insert-only housing that is inserted into the orifice opening and is the same thickness as the weir wall.

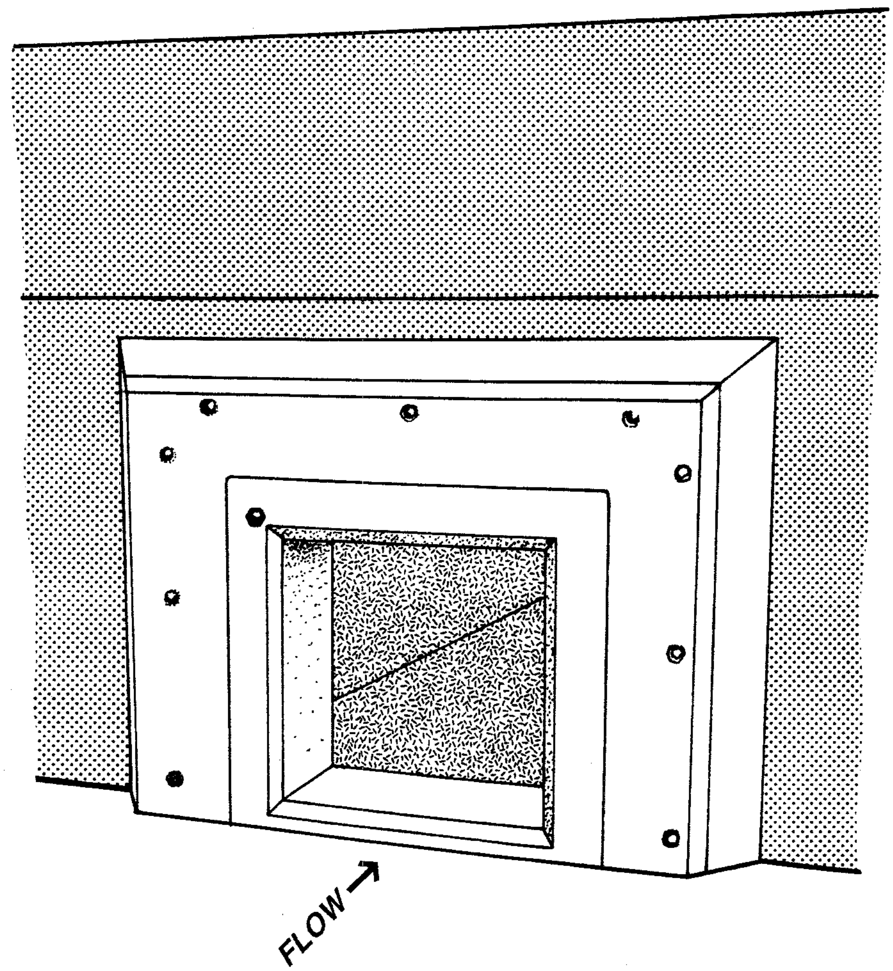

Figure 5. Diagram showing an insert-with-extension housing that is inserted into the orifice opening and extends 12 cm from the upstream face of the orifice.

Continued Operation of the 400-kHz Pass-By (Flat-Plate) and Pass-Through PIT-Tag Interrogation Systems at Bonneville Dam

Introduction

During the past few years, two interrogation systems were installed at Bonneville Dam to interrogate all fish passing through the present juvenile salmon facilities. NMFS installed a prototype 400-kHz pass-by (flat-plate) PIT-tag interrogation system in the downstream migrant (DSM) channel of the Bonneville Dam First Powerhouse in 1996 (Nunnallee et al. 1998). This site is designated BVX in the PTAGIS database. We also installed a pass-through PIT-tag interrogation system and a two-way side-to-side fish diversion gate in the DSM channel of the Bonneville Dam Second Powerhouse in 1997. This site is designated B2J in the PTAGIS database. Both systems have operated smoothly since their installation.

The continued reliable operation of these systems is essential to meet informational needs of fisheries investigators and managers in the CRB. Studies that have used the data collected from these systems include The Dalles Dam spill survival study, *Relative Survival of Juvenile Salmon Passing Through the Spillway and Ice and Trash Sluiceway of The Dalles Dam*; the hatchery PIT-tag *Comparative Survival Study;* and the ongoing Smolt Monitoring Program.

To ensure reliable system operation, we conducted maintenance on both the pass-by (flat-plate) and pass-through systems at Bonneville Dam prior to and during the 1998 field season. In addition, NMFS conducted fish tests to directly determine tag-reading efficiencies at the two sites. These activities are described below.

Maintenance

Pre-season maintenance on both systems was completed by 15 March. During the 1998 field season, there were four interruptions of data collection in the Bonneville Dam pass-by (flat-plate) system. Two of these interruptions occurred when operators inadvertently affected the computer programs responsible for collecting tag codes and mailing the output data files to the PTAGIS database. The other two interruptions were caused by broken signal lines and corrosion of several electronic components in the antenna housing. Data collection was interrupted only once (for one antenna coil) for the pass-through system when a reader card failed. On all occasions, the problems were corrected within 24 hours of notification.

Fish Tests for the Pass-By (Flat-plate) Interrogation System

The pass-by (flat-plate) system was evaluated for reading efficiency using 94 chinook salmon on 19 March 1998 and 99 coho salmon (*O. kisutch*) on 30 April 1998. Tests were conducted under normal water depth operating conditions for fish monitoring. In both tests, fish were introduced one at a time into the DSM channel about 18-m upstream from the PIT-tag interrogation system. Overall reading efficiencies for the two coils combined were 86% and 100% for the March and April tests, respectively.

Results from the March test were not thought to be representative because biologists observed that the fish appeared stressed toward the end of the test. Unlike fish used in previous tests, these chinook salmon had been held for several weeks in holding containers, and in addition, on the day of release the fish were netted from a small holding container. Test results confirmed the biologists' observations. Of the first 25 fish released, 21 were detected on both coils, while 4 fish were detected on 1 coil. These reading efficiencies for individual coils (85-90%) were similar to values we obtained in 1996 and 1997. However, 50% of the subsequently released fish (n = 69) were read on only a single coil.

Since the electronic equipment showed no change during the test, this sudden reduction in reading efficiency was thought to be due to fish changing orientation as they passed over the interrogation coils. Fish passing over the antennas at angles greater than 45° would not have been detected, and the weak and stressed condition of the fish could account for an orientation change due to reduced swimming ability.

A test in April was conducted 2 days after tagging the coho salmon. The fish showed no signs of stress during the release. The combined reading efficiency of 100% for both coils was similar to results we obtained in 1996 and 1997 (97.3% for both years) and was thought to be representative of the reading efficiency of the system. The electronic equipment showed the same values as they had during the chinook salmon test. Furthermore, no changes to the electronic equipment had been made between tests.

Fish Test for the Pass-Through Interrogation System

The pass-through system was evaluated for reading and gate efficiencies with 108 chinook salmon on 18 March 1998. Prior to testing with fish, delay times for each of the four coils above the fish diversion gate were established with tests using tagged sticks. The open time for the gate was 4.5 seconds for all four coils. During the evaluation, PIT-tagged juvenile fish were introduced one at a time about 4-m upstream from the collector that leads to the PIT-tag interrogation unit.

Overall reading efficiency for the four coils combined was 98.2%. The audible sound of the diversion gate operating was confirmed for each of the 106 fish read; furthermore, none of these tagged fish was detected in the sampling room (where they would have gone had the gate missed diverting them). These results are similar to those obtained in 1997 (99.1% for 114 chinook salmon).

The pass-through system was removed at the end of the 1998 field season in preparation for the new juvenile salmon collection and interrogation facility presently being constructed by the COE. A temporary pass-through PIT-tag interrogation system will be installed by NMFS and will be functional for the 1999 field season (this is COE-supported work). This 400-kHz system will be replaced with an 134.2-kHz ISO-based system for the 2000 field season.

Conclusions and Recommendations

The two interrogation sites performed well during the 1998 season, and data generated at these sites have become critical to many research projects. For this reason, there was extensive support for a temporary facility to replace the pass-through system, even though it will only be used for one season. NMFS will install the temporary PIT-tag interrogation system at the Bonneville Dam Second Powerhouse outfall in time for the 1999 field season and will also continue to operate the pass-by (flat-plate) system in the downstream migrant channel of Bonneville Dam First Powerhouse during 1999.

Three-Way Side-to-Side Fish Diversion Gate

Introduction

In 1997, NMFS constructed a prototype three-way side-to-side fish diversion gate measuring 25 cm in diameter. The prototype was based on the two-way side-to-side diversion gates installed at Little Goose and Bonneville Dams (Fig. 6). The general operating principle for these gates is that fish pass through a flexible hose section connected to a track, which is moved sideways to different diversion pathways. The developers were concerned about hose fatigue with the longer side-to-side travel distance of the three-way diverter compared to the short lateral movement of the two-way diverter. Indeed, two material formulations for hoses tested in 1997 failed long before reaching the performance objective of 80,000 cycles, which is estimated to equal 2 years of operation. To rectify the hose fatigue problem, the length of the flexible hose was extended 10 cm and a new polyurethane hose formulation was tried. The new hose was evaluated in 1998.

Results from the 1997 evaluation using fish were inconclusive as to whether the three-way diversion gate caused any new scale loss or other injuries to test fish. As a precautionary measure, modifications to the diverter's pathway dividers (slope and spacing) were made before a new fish test with a more direct approach was conducted in 1998. The hose cycle and fish tests conducted in 1998 are described below.

Mechanical Evaluation

In April 1998, a hose cycle test was conducted at the NMFS Pasco Field Station with the new hose full of water. Unfortunately, only 15,000 cycles had been completed when stress marks were seen. The hose manufacturer (Griffith Polymers Inc.[1] of Tualatin, OR) was contacted and they produced another hose using yet another formulation. This hose passed the 80,000 cycle test, performing over 100,000 cycles at a rate of 1 cycle every 3 seconds (1 cycle = one complete movement from center to right to center to left to center positions). At the end of the test, no stress marks were evident in the hose. Mechanical components have continued to be very reliable: they have been cycled over 250,000 times without any evidence of wear.

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

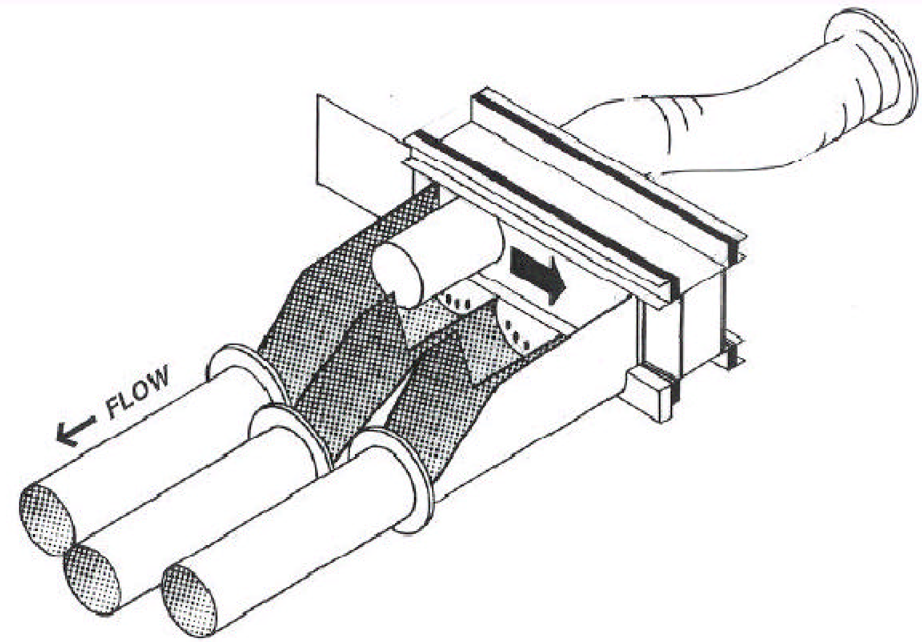

Figure 6. Diagram of a three-way side-to-side gate, a type of fish diversion gate.

Biological Evaluation

On 6 and 7 July 1998, three tests were conducted to determine whether fish could be injured by the three-way side-to-side diversion gate. Juvenile chinook salmon ranging in fork length from 102 to 115 mm (mean length = 107 mm) were used in the tests. Except for the exit position of the flexible hose, general test conditions were kept constant. Fish were examined for abrasion marks and scale loss before they were released. Fish were released, one at a time about 5-m upstream from the diverter and allowed to volitionally pass through the diversion gate. Water velocity was maintained at 2.8 m/sec. Fish were collected in raceways and reexamined 3 or 12 hours later for abrasion marks and other injuries.

All three tests were videotaped with the camera focused on the pathway divider and hose nozzle; the tapes were later reviewed to determine fish response to the various test conditions. Since the major concern was that fish might become injured if they contacted the pathway dividers as the nozzle changed position, this possibility was evaluated directly in the second test, while more realistic conditions were evaluated in the third test. The first test was designed as a control to see if fish were injured due to passing through the diverter with no possibility of coming in contact with a divider.

Test 1

In the control test, the discharge nozzle of the diverter was set so that the hose emptied directly into the center diversion pathway (see Fig. 6). A total of 101 fish were released and then reexamined 12 hours later for abrasion marks and other injuries. No mortalities were observed, and the post-test examination actually showed a reduction in the number of observed abrasion marks from 13 to 3 relative to the pre-test examination.

We believe that the difference in observed marks was due to fish changing to a darker color between the two examinations. The raceway was darker than the initial holding tank, and the darker color of the fish probably masked some of the more subtle abrasions noted earlier. More importantly, none of the abrasion marks observed in either the pre-test or post-test examinations appeared to be fresh. In addition, we did not observe any occurrences of bent operculums, bruising, or behavioral changes in the fish.

These results indicated that fish were not injured by transiting the diversion gate under conditions that prevented them from coming in contact with a pathway divider. A review of the videotape revealed that fish exited the hose and passed through the central diversion pathway in both head-first and tail-first orientations.

Test 2

In the second test, the discharge nozzle of the diverter was centered directly on a pathway divider, which split the water equally between the center and left diversion pathways. Under this configuration, fish were very likely to encounter the pathway divider before being forced to exit via one of two pathways. Our assumption was that this was the condition most likely to injure fish and represented the worst-case scenario. We released a total of 101 fish, but unfortunately, only 57 fish were recovered from the two raceways after the 12-hour holding period: a retaining screen found partially ajar had enabled some fish to escape. Most remaining fish had gone down the left diversion pathway. The pre-test examination had found 10 out of 101 fish with abrasions. The post-test examination found abrasions on 5 out of the 57 fish captured, or basically the same percentage (10%) of abrasion as found in the pre-test examination.

Although as in Test 1, the fish were darker during post-test examinations, none of the observed abrasion marks looked fresh. Furthermore, there were again no bent operculums, bruising, or behavioral changes in the fish. The videotape revealed that fish passed through the hose and diversion pathways in all orientations (most were head or tail first, but some were also sideways). Several fish were seen approaching the pathway divider straight on, but none was seen making actual contact. A water buffer appeared to form in front of the pathway divider that prevented fish from impacting the divider, and the hydraulic flow then forced the fish to choose one side or the other of the divider. Thus, modifications to the divider appeared to be effective in preventing injuries to the fish.

Test 3

The third test was conducted with the diversion gate in the continuous cycling mode (3 seconds for each cycle). Fish (n = 106) from the previous tests were released, and all of them were present when they were reexamined 3 hours later. Twenty-six fish that were recovered had gone down the right diversion pathway, 53 had gone down the center diversion pathway, and 27 had gone down the left diversion pathway. These observed numbers are consistent with the expected values based on the nozzle being in the center position twice as long as it was in either side position. As with the previous two tests, none of the observed abrasion marks looked fresh. Again, videotape revealed fish passing through the diversion gate in all orientations. In addition, several fish were seen approaching the pathway divider, but none was seen to make actual contact.

Conclusions and Recommendations

After many tries, a polyurethane hose formulation was found that could pass the 80,000-cycle test. In addition, modifications to the pathway dividers appeared to help prevent injuries to fish, even when fish were aimed directly at a divider. Therefore, the three-way side-to-side diversion gate has passed all preliminary mechanical and biological tests, and we recommend that it be evaluated at a dam as the final step in its development. We propose to test it at either Lower Granite or Little Goose Dam. At Lower Granite Dam, it would replace the present three-way rotational gate. At Little Goose Dam, it would be installed as part of a remodeling project planned for the PIT-tag diversion system.

Separation-by-Code System: Computer Program (MULTIMON)

Introduction

During 1992-1994, NMFS developed and evaluated a separation-by-code system (computer program and fish diversion gates) at their Manchester Research Station. The computer program controls the separation of targeted PIT-tagged fish from untargeted tagged and untagged fish based on their individual tag codes. Since 1996, this computer program has been called MULTIMON. The development of MULTIMON is a joint project with Pacific Northwest National Laboratory (PNNL), whose personnel write the computer code. NMFS personnel oversee the development; test the program after modification; collaborate with PSMFC personnel on technology transfer, maintenance issues, etc. and assist fisheries researchers. PNNL and NMFS personnel have worked together on the program's online help file (accessible while the program is running) and user guide.

The separation-by-code system was first tested at Lower Granite Dam in 1995; however, the computer program has changed a great deal since then. For example, in 1996, modifications were made to MULTIMON to facilitate the evaluation of 134.2-kHz ISO-based PIT-tag transceiver systems. Thus, the program can now simultaneously function with both 400-kHz and 134.2-kHz transceivers. In addition, each year has seen modifications to make the program more user friendly and new features added to assist researchers in completing their studies. Furthermore, technological advances have changed computers dramatically since 1995 and we have taken advantage of these advances to improve MULTIMON.

Because research needs change each year and new equipment (i.e., hardware, software, electronic components) is installed or upgraded, we recognize that MULTIMON is unlikely to ever be totally static. Nonetheless, the program has reached a stage where NMFS and PSMFC agree that after the conclusion of the 1999 field season, the primary responsibility of maintaining MULTIMON will be transferred to PSMFC. As during the 1998 field season, NMFS and PSMFC will share responsibility during the 1999 season.

During the 1998 season, research projects used the separation-by-code systems at Lower Granite, Little Goose, John Day, and Bonneville Dams. These research projects included a University of Idaho study, which collected fish at all of these dams, and the Idaho hatchery survival study, which used MULTIMON to direct 75% of its study fish to the raceways for transportation at Lower Granite and Little Goose Dams. At Little Goose Dam, other projects using the program included a NMFS fish guidance study, a U.S. Fish and Wildlife study on fall chinook salmon, a study by Dworshak Hatchery to examine the physical condition of their steelhead, and a NMFS study using fish tagged with both PIT tags and radio tags. In addition, the COE used MULTIMON to run two fish guidance studies at John Day Dam.

To accommodate these studies, several modifications were made to MULTIMON. These and other modifications scheduled for the 1998 field season are discussed below as well as problems that surfaced during the season. In addition, modifications under consideration for the 1999 field season are described briefly.

1998 Computer Program Modifications

Platform

During the 1998 field season, all of the dams monitored by PSMFC used MULTIMON. Most of these sites used the data-collection platform that includes two personal computers running MULTIMON in DOS that are networked to a SUN computer performing file management tasks in UNIX. However, to save money, the more expensive SUN computers were not used at Bonneville and Prosser Dams. Consequently, before the 1998 season, the largest set of changes made was to adapt MULTIMON so it could run in a DOS window within the multi-tasking Windows 95 platform. This platform allowed closed data files to be automatically e-mailed to the PSMFC server at Gladstone, Oregon while MULTIMON continued to operate. To perform this e-mail function, a program called MAILER was written. In addition, the Windows 95 platform allowed users to open a window that ran the REPORT program to analyze closed output data files without having to stop collecting tag-code data.

Flexibility

Some of the scheduled modifications for the 1998 migration season involved increasing the flexibility of the program for future use. One of these modifications was to increase the number of Action Codes available from 100 to 256. An Action Code is a number assigned to tag codes in the Tag Database file to designate a subgroup of fish. Action Codes are used by MULTIMON to direct a group of fish to a predetermined destination. Furthermore, the number of supported RocketPorts (a communications device that connects many devices to a single device) was increased from 32 to 128, and the number of coils covered by each Diversion Unit was increased from 4 to 5 coils. (This increase was to accommodate the facility at Lower Granite Dam for adult salmon that has five coils.) In addition, the programmer began to compile MULTIMON using the large memory model for C-language programs so that MULTIMON could handle the scheduled changes and any future modifications.

User friendliness

To assist in the future transfer of MULTIMON to PSMFC, changes were implemented to make the program easier for PSMFC to set up. For example, wherever possible, set-up parameters were converted to selectable options instead of the user having to type in the parameters. In addition, many warning boxes were added, and default settings were established for the Map and Hardware files.

Program speed and data output

A function was added so that on the first of each month, all of the previous month's output data files were moved to an archive directory. This function keeps MULTIMON operating at maximum speed because too many files in the data directory can slow the program down. A further modification was added to enable the output data file to print either to serial or parallel printers.

Counters

In 1997, active daily and seasonal tag counters were added to the program to help researchers track their study fish that MULTIMON had processed; however, results from the use of these counters during the 1997 season suggested that a few refinements were needed to make them more effective. The counters count Action Codes, and are used not only to keep track of the numbers of study fish that have been processed, but to stop the diversion of fish after a given number of study fish have been diverted. The most significant modifications for 1998 involved defining the maximum number of fish to be diverted before the program stops diverting for any specific Action Code.

For locations where single gates lead to the collection tank, daily and seasonal maximum columns are defined in the Diversion Unit on the same line as the output signal for each Action Code. However, for locations where multiple gates lead to a common collection tank, it is necessary to combine counters from two or more Diversion Units to reach the correct daily and seasonal maximums. For example, there are two gates at the Little Goose Dam experimental site (GOX), and because there is poor species separation at this dam, researchers wanted to define the maximum number of study fish that can be diverted based on both gates.

Another modification scheduled for 1999 is to gain the ability to directly display the screens for a given Action Code, without displaying screens for Action Codes that are inactive (i.e., counters with all zeroes). This will make it easier to quickly examine the current situation.

There were also several behind-the-scenes changes made with the counter files. For one, the stored counting information was moved from the Map file to the Default.cfg file so that loading new Map files would not impact the counters. Furthermore, to make the counting more accurate so that tagged fish were not counted twice, the number of tag codes maintained in a queue for each coil was increased from two to four.

At the peak of the 1998 season, inaccurate counts were still observed at the Lower Granite Dam experimental site (GRX) and GOX. These counts occurred after large numbers of PIT-tagged fish were released when the PIT-tag head tanks were emptied every 1 to 2 hours. To correct this problem, the counting queue was increased to 16. This 16-code queue was used at the GRX and GOX sites in 1998 and will be used at all sites in 1999.

Subsample

The Subsample section of code was completely rewritten so that MULTIMON could control or monitor two independent timed subsamples (previously, it could only control one subsample). Subsamples can be monitored or controlled using the parallel and serial ports or a program logic controller (PLC) interface.

With the revised subsample code, a user can indicate for each Diversion Unit whether the coils in the unit are impacted by one of the two subsamples or by neither. Thus, when a fish is part of a subsample, MULTIMON can print the Message "SubSpl" instead of "Divert" so that the tag record accurately depicts what happened to that fish. This ability will mean that subsamples do not affect the daily and season maximum counts. For example, if a subsample occurs without MULTIMON's knowledge, MULTIMON would think it had diverted that fish and thus count it as diverted. For a researcher diverting only 5 or so fish a day, this error could be significant.

PSMFC has decided to use PLCs to control fish subsamples at the dams; thus, MULTIMON is set up to monitor the PLC actions. This function was only utilized at John Day Dam in 1998. A PLC bit-definition page was added to the hardware file so that it would be easier to monitor subsamples and other functions that could potentially be controlled by the PLC. This tool will be more fully utilized in the future.

Separation protocols

Two Separation Protocols (5&6) were added to accommodate research projects this year, but future studies will also utilize these protocols (Table 3). Separation Protocols 2, 4, 5, and 6 are typically used at coils above diversion gates, where one wants to apply particular actions to a subset of the PIT-tagged fish (fish listed in the Tag Database file). The subsets are distinguished by having different Action Codes. Separation Protocols 4, 5, and 6 are similar to each other in that they divert *specific subsets* of the tags that would *all* have been diverted by Separation Protocol 2. For Separation Protocol 4, the specific subset of tags is determined by defining the M/N fraction (e.g., separate one out of four fish to be diverted to the river and the other three to be barged). For Separation Protocol 5, the specific subset of tags is determined by defining a range of time for each day during which those fish are to be diverted (e.g., collect fish between 0600 and 0900). During the 1998 migration season, one could not define a range that transcended

Table 3. Information needed by each separation protocol to function properly is listed. The last column lists all of the possible tag record Messages for each Separation protocol. "*NotFound*" messages are attached to tag codes not found in the Tag Database file. "*Monitor_AC*" messages are attached to tag records for Separation Protocols 2, 4, 5, and 6 when the action for their Action Codes has been defined with an 'X' or when "no output signal" is to be sent. This is equivalent to the action applied to tags using Separation Protocol 0 or monitor-only. “*Skip_AC*” messages are attached to tag records after the daily or seasonal maximums have been reached for that Action Code or for fish in the M/N ratio that are not diverted. This informs the user that these fish were not diverted.

	Action Code Used	Input needs	Possible tag record messages
Separation Protocol 0	Tag database	None	Monitor_AC* NotFound
Separation Protocol 1	Default	None	DivertAll
Separation Protocol 2	Tag database	None	Divert_AC NotFound Monitor_AC
Separation Protocol 3	Default	M/N ratio	DivertM/N SkipM/N
Separation Protocol 4	Tag database	M/N ratio	Divert_AC Skip_AC NotFound Monitor_AC
Separation Protocol 5	Tag database	Time range	Divert_AC Skip_AC NotFound Monitor_AC
Separation Protocol 6	Tag database	Julian dates	Divert_AC Skip_AC NotFound Monitor_AC

* The "*AC*" in these Messages would be replaced with actual decimal values of the appropriate Action Codes.

midnight with these times, but this will be possible in 1999. For Separation Protocol 6, the specific subset of tags is determined by defining up to three ranges of Julian dates (e.g., collect study from 114 to 117 and from 128 to 131). Separation Protocol 6 allows a researcher to collect fish over a range of dates without anyone having to change the computer program or the PLC to turn the gates on and off. If more than three ranges of dates are needed, the program administrator can use another Diversion Unit.

Another modification was to add the ability to switch to a different Separation Protocol after a maximum number of fish for an Action Code had been diverted, instead of automatically switching to just recording the tag codes without applying any output signals. This modification would allow a second output signal to be applied to the tag codes after the maximum number was reached.

Problems in 1998

PSMFC installed new PCI (protocol control information) network cards in 1998, which utilized more of the conventional RAM (640 Kbytes) than had the previously installed ISA (industry standard architecture) network cards. This caused a decrease in available RAM, which prevented MULTIMON from operating as designed. To solve this problem, settings for the network cards were adjusted, and several modifications were made to change MULTIMON so it used less RAM at any one time. During the 1999 season, the program will determine if there is enough RAM to operate before it loads (approximately 450 Kbytes). If there is too little RAM available, then it will warn the user.

Two new high-speed 400X readers were installed at Lower Granite Dam to control the slide gates for the Idaho hatchery survival study in 1997. No problems occurred at these locations, so PSMFC installed them at all sites in 1998. However, at several sites during the 1998 season, the 400X controllers caused problems by transmitting nonsense instead of tag codes. The "nonsense" code transmissions were caused by the communications card in the 400X controller inexplicably resetting itself to its default setup parameters, as if the power had been cycled. Although the precise cause was never conclusively determined, power surges were probably the cause. The only difference between the 1997 readers and the 1998 readers were the boxes that housed them. Perhaps the back-planes of the new boxes handled power surges differently. Once the cause was identified, the problem was corrected by initializing the communications card parameters before each tag code transmission.

The MAILER program also locked up computers occasionally during the 1998 season. Changes were made and after July, the program worked flawlessly. Noisy phone lines at Bonneville Dam caused occasional interference problems and so delayed the transmission of files by MAILER; unfortunately, there is no software or easy hardware solution for this problem.

Conclusions and Recommendations

After finding the Windows 95 platform satisfactory in 1998, the next step is to explore other platforms that could take advantage of the advances made in computer technology. PSMFC wants to test incorporating the software program Laplink by Traveling Software as a means to remotely check on the status of the ISO-based transceivers. If this is successful, then most likely the SUN computers could be eliminated or used to run other operations and maintenance tasks performed by PSMFC at these sites. Another possible approach is to make MULTIMON a Windows application instead of a DOS application. This would enable it to run within the Windows NT operating system, which is more stable than Windows 95. Unlike Windows 95, Windows NT will not let a DOS-based MULTIMON control the serial and parallel ports.

The ability to recognize remote commands that would enable PSMFC to manage its data files more effectively from its Gladstone office was added in 1997. The success of this approach in collecting files from the Lower Granite Dam experimental site made us realize that there were other tasks, such as updating tag databases, that would best be performed remotely. However, in the past, the process for sending remote commands has been quite awkward; thus NMFS recommends that an interface program be written for 1999 to make this process straightforward.

Information Transfer, Technical Reviews, and Technical Support

NMFS actively collaborates with other agencies on PIT-tag related matters (e.g., facility designs to accommodate PIT-tag systems, PIT-tag system maintenance, assistance in using prototype equipment and the MULTIMON computer program, and information transfer). Because NMFS personnel designed or co-developed many of the present PIT-tag system components within the CRB, they are an important resource for providing technical support and training to ensure the reliable operation of PIT-tag technology throughout the CRB. Activities that NMFS was involved in during the 1997-1998 reporting period are outlined below.

- Provided assistance to PSMFC regarding the repair of PIT-tag interrogation systems, ancillary equipment such as fish diversion gates, and setting up MULTIMON at CRB dams.

- Reviewed drawings of the collection facility for juvenile salmonids that the COE is building at Bonneville Dam.

- Published a paper on the 400-kHz flat-plate PIT-tag interrogation system installed at Bonneville Dam in *Aquaculture Engineering*.

- Provided classes to fisheries investigators on the use and operation of CRB PIT-tag fish diversion and separation-by-code systems (including MULTIMON).

- Assisted investigators from several fisheries agencies in setting up the MULTIMON program to accommodate their separation-by-code requirements.

- Participated in the 1998 Manchester Research Station Open House by providing demonstrations of PIT-tag equipment used in CRB. The Open House was a community outreach program highlighting activities associated with the research station.

- Provided information on the CRB PIT-tag system to numerous national and international investigators. For example, consultation was provided to investigators from Sweden and Iceland on their use of PIT-tag systems for solving fisheries problems.

- Designed and fabricated electronic components for the towed tunnel array used in the Columbia River estuary by another NMFS project (Ledgerwood et al. 1997). We also assisted in the design of the tunnel array.

- Designed a 400-kHz pass-by PIT-tag interrogation system for detecting tags deposited by birds in sand. The system was designed to be towed by a jeep.

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REFERENCES

Ledgerwood, R. D., E. M. Dawley, B. W. Peterson, and R. N. Iwamoto. 1997. Estuarine recovery of PIT-tagged juvenile salmonids from the Lower Granite Dam transportation study, 1996. Report to the U.S. Army Corps of Engineers, Contract E8960100, 54 p. plus appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Nunnallee, E. P., E. F. Prentice, B. F. Jonasson, and W. Patten. 1998. Evaluation of a flat-plate PIT-tag interrogation system at Bonneville Dam. Aquaculture Engineering 17: 261-272.

Prentice, E. F., S. L. Downing, E. P. Nunnallee, B. W. Peterson, and B. F. Jonasson. In press. A study to determine the biological feasibility of a new fish tagging system (1996-1997). 39 p. Report to Bonneville Power Administration, Contract DE-A179-84BP11982, Project 83-319.

APPENDIX A: FISH TESTS PERFORMED AT JOHN DAY AND McNARY DAMS

During August 1998, a multi-agency team conducted fish tests at McNary and John Day Dams to determine if the ISO-based stationary PIT-tag interrogation system performed as well as or better than the present 400-kHz system. This information was critical for helping to decide whether the fisheries community should proceed with the transition for the year 2000 smolt migration.

McNary Dam

Tag-Comparison Test

Test fish (fall chinook salmon) were tagged at Priest Rapids Hatchery. The tag-comparison test at McNary Dam compared four ISO tags (12 mm and 13.5 mm tags produced by Destron-Fearing and Datamars; abbreviated as DF12, DM12, DF13, and DM13) to 400-kHz tags using the same monitor (the B-raceway ISO monitor whose coil IDs are A1-A4) so that hydraulic conditions would be equal. All other conditions were also kept as constant as possible.

Approximately 500 fish tagged with each type of ISO tag and 400-kHz tags (1998 generation) were used. All fish were scanned before they were released so actual numbers could be used to calculate reading efficiencies (REs) for the different coils and monitors instead of relying on the estimated RE values that PSMFC publishes daily.

All of the individual coils had RE values above 95% for DM12, DF13, and DM13 ISO tags, but not for the DF12 and the 400-kHz tags (Table A1) . However, all of the two-coil combinations for DF12 and the 400-kHz tags had RE values above 97% (the stated goal for the 400-kHz system is an RE at or above 95% for two coils with monitors in locations with good tag orientation and hydraulic conditions). Thus, the ISO-based system performed as well as or better than the 400-kHz system in this test.

Table A1. Results of reading efficiency (RE) tests comparing 134.2-kHz ISO-based tags with 400-kHz tags.

Tag type	Overall RE (%) (all four coils combined)	Individual REs (%)			
		A1	A2	A3	A4
DM12	99.5	95.7	97.4	96.2	95.9
DM13	99.4	96.1	96.5	96.3	95.5
DF12	99.8	93.1	95.8	92.3	94.3
DF13	100.0	96.3	96.3	96.3	95.9
All ISO	99.7	95.2	96.4	95.2	95.3
400	99.5	86.7	96.7	92.2	95.4

Whole-Dam Test

In the whole-dam test at McNary Dam, approximately 3,500 fish tagged with DF12, DM12, and DM13 tags were released above the fish-and-debris separator and mostly allowed to transit the bypass/collection facility volitionally. Again, all fish were scanned first. The 12 individual coils or stationary transceivers installed at McNary Dam read the three tag types equally well with an average RE of 92.8% ± 1.04% (± standard deviation). The RE values for individual coils were lower than in the tag-comparison test. Most likely this was due to groups of fish going through the coils together (two tags cannot be read if they are in the electromagnetic field simultaneously); we had carefully avoided grouping during the tag-comparison test. In fact, the effect of grouping was obvious when the separator was lowered at the end of the second day of testing and high numbers of tags transited the coils simultaneously (this significantly reduced the instantaneous RE values computed by PSMFC). This reduction is similar to what normally happens when the PIT-tag head tanks are lowered at the bypass/collection facilities.

John Day Dam

The tests at John Day Dam determined RE values for the six installed ISO coils (coil IDs of 20, 21, 22, 23, 90, and 91) and for two 400-kHz coils (coil IDs of 94 and 96) (Table A2). For the ISO-based system, only DF12 tags were used. Approximately 500 fish were tagged to test Coils 20-23, 500 fish for Coils 90&91, and 350 fish for Coils 94&96.

Except for one ISO coil that had an RE of 94.5%, all of the individual coils had RE values above 95% for both systems. The ISO-based stationary transceivers performed as well as the 400-kHz system and they had not been touched since they were installed in June.

Table A2. Results of reading efficiency (RE) tests comparing 134.2-kHz ISO-based DF12 tags with 400-kHz tags from the fish test at John Day Dam.

	REs (%) for individual coils							
Tag type	20	21	22	23	90	91	94	96
DF12	96.1	97.4	94.5	97.4	97.1	95.4		
400							97.7	95.9

Conclusions and Recommendations

The ISO-based system performed as well as or better than the 400-kHz system in all of the fish tests. Therefore, the results support proceeding with the transition for the year 2000 smolt migration. In addition, the results demonstrated that the shorter DF12 tag should be satisfactory for fisheries research (BPA has a contractual agreement to purchase these tags through 2001). Furthermore, the results support installing three coils instead of four coils in monitors previously identified as less critical.

The results also suggest approaches for improving RE values: 1) the flumes should be covered above, between, and below the installed shields to reduce sudden changes in fish behavior due to changes in light-dark conditions and 2) to avoid high tag densities, the PIT-tag head tanks should be emptied more often than once an hour.